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AD-A213 363

The Economic Impact of Automation Technology

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CMU-RI-TR-89-13

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Pittsburgh, Pennsylvania 15213

July 1989

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION: Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT: Approved for public release; distribution unlimited

4. PERFORMING ORGANIZATION REPORT NUMBER(S): CMU-RI-TR-89-13

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION: The Robotics Institute, Carnegie Mellon University

6b. OFFICE SYMBOL *(If applicable)*

7a. NAME OF MONITORING ORGANIZATION

6c. ADDRESS *(City, State, and ZIP Code)*: Pittsburgh, PA 15213

7b. ADDRESS *(City, State, and ZIP Code)*

8a. NAME OF FUNDING / SPONSORING ORGANIZATION

8b. OFFICE SYMBOL *(If applicable)*

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS *(City, State, and ZIP Code)*

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)*: The Economic Impact of Automation Technology

12. PERSONAL AUTHOR(S): Aydan Kutay

13a. TYPE OF REPORT: Technical

13b. TIME COVERED: FROM ______ TO ______

14. DATE OF REPORT *(Year, Month, Day)*: July 1989

15. PAGE COUNT: 24

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*: economic analysis technique

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

There is a growing consensus among academicians, business leaders and government officials that the American competitive problem rests centrally on the slowing rate of investment to integrate new automation technology into manufacturing operations. Although the source of major innovations in automation technology is from United States universities and research centers, American firms have been too slow in adopting these technolgies. One of the major factors underlying this problem is the lack of an economic analysis technique specifically aimed at estimating the benefits of automation technology. This paper offers an economic analysis technique based upon the premise of increased probability of capturing the market segments through economies of scope. The paper first demonstrates the inadequacy of current economic analysis techniques to assess the benefits of automation technology, then proposes a new methodology which can be integrated to an expert system to assess the economic impact of various types of automation technology.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION: Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL

22b. TELEPHONE *(Include Area Code)*

22c. OFFICE SYMBOL

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

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ABSTRACT

There is a growing consensus among academicians, business leaders and government officials that the American competitive problem rests centrally on the slowing rate of investment to integrate new automation technology into manufacturing operations. Although the source of major innovations in automation technology is from United States universities and research centers, American firms have been too slow in adopting these technologies. One of the major factors underlying this problem is the lack of an economic analysis technique specifically aimed at estimating the benefits of automation technology. This paper offers an economic analysis technique based upon the premise of increased probability of capturing the market segments through economies of scope. The paper first demonstrates the inadequacy of current economic analysis techniques to assess the benefits of automation technology, then proposes a new methodology which can be integrated to an expert system to assess the economic impact of various types of automation technology.

1. INTRODUCTION

It is a well-documented fact that the American economy has been losing its competitive edge relative to its major trade partners, Japan in particular. Between 1970 and 1987, for example, real production of manufactured products has more than doubled in Japan but has increased only by 50 percent in the United States (Kutay, 1989).

There is abundant evidence that productivity grows more rapidly in countries where investment in new plant and equipment is highest. In fact, there is a growing consensus among academicians, business leaders and government officials that the American competitive problem rests centrally on the slowing rate of investment to integrate new automation technology into manufacturing operations (Kutay, 1989; Hayes et.al., 1988; Cohen and Zysman, 1987). Although the source of major innovations in automation technology is U.S. universities and research centers, the American firms have been too slow in adopting these technologies.

One of the major factors underlying this problem is the lack of an economic analysis technique specifically aimed at estimating the benefits of automation technology. This paper attempts to fill this gap by offering an economic analysis technique based upon the premise of increased probability of capturing the market segments through economies of scope.

In the subsequent sections of the paper, it is first demonstrated that the conventional economic theory upon which the current economic impact methods are based can not assess the economic benefits of automation technology. In the mass production system, capital investments in new technology could usually be justified by their potential to replace human labor by machines to improve productivity. In the new system of flexible production, however, the economic foundations of the benefits derived from automation technology are fundamentally different from the benefits obtained from capital investments on new technology in the mass production system. The use of conventional methods of economic performance, such as productivity improvements, would merely be a mismeasurement of the potential benefits that could be obtained from automation technology.

In section two, a new conceptual framework is developed to evaluate the economic impact of automation technology. The new conceptual framework suggests that the economic foundation of the benefits of automation technology is the economies of scope based upon the premise of shorter lead times, increased flexibility in production, and improved product quality.

In section three, it is demonstrated that the economic impact of automation technology, considered 'intangible' and therefore left unquantified in conventional economics, can be evaluated through potential gains in inventory costs, sales revenue, and lower operating and labor costs due to improvements in lead times, flexibility in production, and product quality. It is suggested that the entire analysis can be integrated into a standard economic justification technique such as Discounted Cash Flow analysis, to make it understandable to company managers, accountants, and economists. An

expert system can then be developed to aid the users of automation technology to identify the benefits they may obtain from its implementation.

Once the model of economic impact analysis of automation technology developed in this paper is tested, the ultimate goal is to develop an expert system to achieve the following:

1. Prior to the integration of a new technology, the expert system will enable a company to identify the areas in the manufacturing process in which the use of automation technology would be economically viable,

2. If the company is interested in developing a new technology, the expert system will guide company managers to make a better allocation of the research and development funds into areas which give the best return on investment.

3. The expert system will enable companies to make a better specification of the general range of conditions where new technologies can generate acceptable returns to justify their investment.

The arguments supporting the line of reasoning set forth in this paper need to be empirically verified by further research. This effort, nevertheless, is meant to provide a new methodology upon which future economic impact studies of new automation technology may be based.

2. THE NEED FOR A NEW CONCEPTUAL FRAMEWORK TO ANALYZE THE ECONOMIC IMPACT OF AUTOMATION TECHNOLOGY

In recent years, a growing body of literature has developed on the fundamental changes in the production process facilitated by the new automation technology. The research in this area, however, tends to emphasize either direct labor displacement effects without considering the changes in the nature of work (for example Ayres and Miller, 1983), or tends to be advocacy type of efforts which assert the existence of certain benefits from automation technology without explaining the precise source of these benefits (Hayes et.al., 1988; Cohen and Zysman, 1987; Jelinek and Goldhar, 1984).

The first economic or societal impact studies of automation technology overwhelmingly emphasized labor displacement issues which unfortunately encouraged the formation of a hostile attitude toward automation technology particularly on the labor side. While it is true that automation technology replaces human labor directly involved in the production of goods on the factory floor, it creates more jobs in processes involved in the production of goods. Automation technology transforms the nature of work from directly contributing to the production of finished goods to contributing to production indirectly by generating information to reduce uncertainty in decisions related to the production, exchange, circulation, distribution and consumption of goods (Cohen and Zysman, 1987). Consequently, more jobs are created in setting up the production systems, in designing the products, in R&D efforts, and in finance, marketing, and distribution stages of production. Direct human labor in

production has nevertheless been reduced for repetitive and hazardous tasks where displacement is more advantageous for labor in the long term.

One of the key arguments of this paper is that the lack of an economic analysis technique specifically aimed at assessing the benefits of automation technology is the major cause of the confusion observed in the prior studies of automation. In the next section we direct the attention to the inadequacy of conventional economic theory to assess the benefits of automation technology.

2.1. The inadequacy of conventional economic theory to assess the benefits of automation technology

The foundations of traditional economic theory were developed during the time of the industrial revolution when mass production and mass consumption prevailed in the world economy. In the system of mass production, the major production strategy to expand profits was to increase the *size* of the *total* target market. The major dilemma a firm faced to meet competition was therefore to lower unit costs to expand the size of the market for its product(s). The unit costs were lowered through economies of scale (i.e., producing an increasing quantity of the same product) and by lowering labor and raw material costs through capital investments. The economic performance of a firm, an industry, or the larger macro economy was therefore evaluated by 'productivity' which measured the increase in output relative to a unit increase in capital, labor and raw materials.

The first recognized methods to increase productivity were:

I) To increase the division of labor, and

II) To delegate repetitive tasks to machinery.

These methods became economical at higher outputs sourcing in scale economies. Adam Smith's famous division of labor and its heightened productivity from performing a single repetitive task could only be achieved by increasing the division of labor and specializing jobs into repetitive tasks which could then be replaced by machines. Capital investments in new technology could therefore be justified by their potential to replace human labor with machines to increase productivity.

Finally, productivity improvements through the increased use of machinery was only possible through further standardization of products which led to a substantial decline in unit production costs. Given the emphasis of lowering the unit costs of standardized products to expand the total target market size, productivity was perfectly relevant to measure economic performance in the system of *mass* production.

Once the world markets began to saturate during the 1960s and the 1970s, it became increasingly clear that mass production of standardized products was no longer profitable since the size of the total target market could not be expanded. At the same time, with an increase in international competition, the number of manufacturers attacking a market multiplied, resulting in a large number of differentiated product versions on the market. The emphasis to gain the markets shifted from economies

of scale to economies of scope. That is, manufacturers produced a variety of products to satisfy a far greater range of market needs by increasing the capacity to manufacture goods cheaply in small batches. Even if the size of the total target market could not be increased (or even if the size of the pie could not be expanded), economies of scope ascertained that the *probability* of actually capturing the targeted total market could be increased through product differentiation. New trends toward internationalization of the world economy also increased competition which, in turn propelled the need to shorten the period of time necessary to introduce a variety of products to the market in small batches. As one can see, these trends in flexible production were in contrast to the way firms competed in the system of mass production by producing large quantities of similar products. The new automation technology consequently became crucial in production since it improved product lead-time, product quality, and the capability to increase product diversity.

Once the rules of the economic system started to change, one expected to a see a change in the performance measures of the economic system. While the measure of economic performance through labor, raw material, and multifactor productivity were perfectly relevant in the system of *mass* production, these techniques were inadequate to measure economic performance in *flexible* production.

The key point is that, the economic foundations of the benefits derived from new automation technology are fundamentally different from the benefits obtained from capital investments in the mass production system. The use of conventional methods of economic performance, such as productivity, would merely mismeasure the potential benefits that could be obtained from automation technology. The main benefits of automation technology, such as reduced lead times, faster response to market shifts, and increased flexibility in product differentiation, do not enter into the calculus of the conventional measures of economic performance. It is no wonder that productivity studies of information technology conclude that user firms have not experienced productivity gains from automation technology and that the investment in other technologies would be more beneficial (Loveman, 1988). Firms which were the early users of automation technology do experience increases in employment. The conventional measures of economic performance which regard reduction in labor costs due to capital investments as a positive change, only mislead us. The recent productivity measures developed by the Bureau of Labor Statistics (Dean and Kunze, 1988), on the other hand, consider technological change or multifactor productivity as the unexplained residual in output growth without providing any measure of how much of the increase in multifactor productivity could be attributed to automation technology.

Let us review the basic calculations of productivity to support this argument. The most common measures of productivity calculate the growth in output due to growth in capital and labor inputs. The rate of growth in output per hour of all persons employed in a firm or industry is recognized as 'labor productivity', and the rate of growth in output per unit of capital services is recognized as 'capital productivity'. In recent years, the Bureau of Labor Statistics (BLS) has started to measure multifactor

productivity by calculating the portion of growth rate in output that cannot be accounted for by the growth rate of combined inputs of labor and capital and is therefore attributed to technological change. The term named as multifactor productivity (or what BLS recognizes as the benefit derived from technological change) is actually the unexplained residual in the calculation. BLS does not even provide a method to attributing changes in the growth rate of output due to specific technologies such as automation. These formulations have been derived from the production function $Q = A\ f(K,L)$, where A represents the state of the technology and Q, K, and L denote output, capital and labor respectively. Nowhere in this calculation can the potential benefits of automation technology such as product quality, the length of lead time, product differentiation, and flexibility be evaluated.

The conventional methods of measuring economic performance served us well when the basic dilemma faced in the production process was to reduce the unit costs through economies of scale to expand demand for a standardized product. Inflexible manufacturing based upon the economies of very large scale production of standardized products, however, severely limits the number of product versions. Retooling of a plant or a production line to meet the customer demand which a competitor is challenging, usually means the sacrifice of another market segment unless new plants are added to the manufacturing capacity with substantial costs. The long lead times from the conception of a new product to production reduce the ability of the firm to meet competition on a timely basis. Automation of manufacturing operations is, therefore, absolutely necessary to compete successfully in the system of flexible production.

What is needed most is the development of new measures of economic performance which can evaluate the economic impacts of automation technology in the system of flexible production. In the next section, we review the current methods used to assess the economic benefits of automation technology in U.S. firms and suggest that these techniques are ineffective in evaluating the economic benefits that can be obtained from automation technology.

2.2. The inadequacy of economic impact analysis methods to evaluate the benefits of *automation technology*

The economic impact analysis aimed at integrating new technology or equipment into the manufacturing operations of U.S. firms is in the form of a capital investment procedure which typically allocates current resources in the prospect of future returns. The principles of these techniques were laid down in 1934 when labor was the chief variable cost and when mass production propelled U.S. industry to world dominance These techniques simply shaped and generated decisions in such a way that a required level of financial attractiveness was achieved by simply focusing on short term financial goals and responding to the implied needs of a forecasted future by reducing labor costs.

Over the last 20 years, however, direct labor costs have been reduced to about 10 to 12% of the total production costs (Kutay, 1989). The major attributes of many of the new technologies are, for

example, long term strategic goals such as the product quality, delivery speed and reliability, and the rapidity with which new products can be introduced to the market. Yet the pool of labor from which the savings would come to justify the investment on new technology has dwindled. Given the focus on reducing labor costs, strategic factors cannot be quantified within a traditional economic analysis. Therefore, capital investment on fundamentally different technologies is much more difficult to justify in economical terms. Retaining the existing manufacturing equipment consequently performs as a better alternative than investing in new technology.

The reluctance of many U.S. companies to adopt new technologies, therefore, partly reflects the inability of traditional economic analysis procedures to evaluate the long term strategic benefits of automation technology. Firms which could achieve substantial benefits from new technologies may fail to use them simply because there is no acceptable methodology to quantify the return on investment.

Existing literature, when describing the advantages of new automation technology, suggests that a large number of 'intangible' benefits exist which, by implication, are unquantifiable and thus are precluded from any rigorous economic evaluation (Cohen and Zysman, 1987; Meredith, 1986). Recent reports on the progress of automation in American manufacturing (Business Week, 1987, 1988) suggest that top management often accept the automation technology as being a 'justifiable act of faith on a strategic technology' and implement them without the necessary understanding of the implications critical to their successful operation. This approach still poses serious problems. First, although it is less likely that such strategic investments will be turned down by standard procedures because they do not meet traditional financial criteria, it tends to be highly dependent on a selection process that separates 'strategic' from 'nonstrategic' investments. Unfortunately, most U.S. companies treat the choice of manufacturing technology as a 'nonstrategic' issue (Hayes et;al., 1988). Most proposals of the investment on new equipment, therefore, end up getting evaluated within the standard budgeting process.

Second, the process of automation through the use of automation technology represents a long term commitment, with implementation extending over several years. The lack of quantifiable objectives prevents progress from being monitored in financial terms which are understandable to management. Without defined financial objectives, any disruption can be used to abondon the new technology whose economic benefits are realizable in the long term. Kaplan (1986) suggests that problems arise because the benefits of new technology are not defined in financial terms that top management can understand. American machine tool suppliers, for example, are not fully committed to the production of new robot systems because they perceive that if their potential customers cannot clearly identify defined economic justifications then they will not purchase such systems (American Machinist, 1988). These difficulties can be overcome if a new conceptual framework which can quantify the 'intangible-strategic' benefits of automation technology is developed and is integrated in a

standard economic analysis procedure acceptable to company managers, economists, and accountants.

3. THE CONCEPTUAL FRAMEWORK FOR ECONOMIC IMPACT ANALYSIS

As pointed out in the previous section, the benefits derived from new automation technology are fundamentally different from the benefits obtained from capital investments in the mass production system. Using the conventional methods of economic performance would only mismeasure the potential benefits that could be obtained from new automation technology. The main benefits of automation technology such as reduced lead times, faster response to market shifts, and increased flexibility in product differentiation as well as its significantly enhanced capabilities to produce complex products of higher quality and reliability levels, do not enter the calculations of the conventional measures of economic performance. In this section, a new conceptual framework which can readily integrate the benefits of automation technology into the calculations of the improvements in economic performance, is developed.

3.1. Economies of scope: The economic foundation of the benefits of automation technology

The economic foundation of the automation technology is the economies of scope as opposed to economies of scale which necessiates a paradigm shift in the way we measure economic performance. Economies of scope are said to exist if a single plant can produce a variety of products at lower unit cost than a combination of separate plants each producing a single product at the given level of output. More formally, there are increasing returns to scope to a plant producing X and Y if

$$C(X,Y) < C(X,O) + C(O,Y)$$

where X and Y are the given levels of output of each product and C(.) are their respective cost functions.

Automation technology has the potential to make it just as cheap to produce say fifty different versions of a product as it is to produce fifty identical pieces of a given product. The fundamental production problem faced by firms today is to capture different segments of a broadly defined market with different tastes. If, for example, refrigerators constitute a broadly defined market, a given firm may produce a number of different models each of which is aimed at capturing a subsection of that broadly defined market for the firm. This can be made possible by producing a certain model with the attributes which no other firm competing for the same market can produce. In this new system of flexible production, firms no longer confront a situation of single uniform demand for a commodity called refrigerator (as it was under the mass production system), but face distributed demands for different types of refrigerators: some with ice makers, some with double doors, some powerful, some small and so on. Offering a standard model which only comes in white is not likely to suffice in capturing the entire market for refrigerators. In the flexible production system, as the consumer tastes become diversified

and more complex, manufacturers must identify the segments of consumer demand within which tastes and purchasing power are relatively uniform. They must then offer those segments the products that closely match each segment's expectations.

The markets are no longer as predictable as they used to be under the mass production system. They have become more uncertain and complex. In order to quantify the benefits derived from automation technology in this new system of production, we have to move away from the traditional concept of "product" in conventional economic theory. Products should not be defined as physical commodities but should be conceptualized as a bundle of characteristics sought after by consumers. Going back to the refrigerator example, these characteristics may be size, color, interior room, exterior image, reliability, and energy consumption. We, therefore, can conceptualize a product as an n-element vector:

$$X = (x1, x2, x3, \ldots\ldots, xn)$$

where 'xi' is the product characteristics

In the same n-dimensional space, a given consumer can be conceptualized in the form of a characteristics vector:

$$C = (c1, c2, c3, \ldots\ldots\ldots, cn)$$

where 'ci' is the characteristics the consumer seeks in a product

If $x=c$ in the case of a given consumer, the probability for this consumer to buy the product should be 1. If $x \neq c$, the probability of a sale to that consumer is less than one.

Given the conceptual framework above, we can measure the performance of a firm not by growth rate of output relative to a change in labor and capital (as is the case in measures of productivity), but rather we measure the performance of a firm through the degree of product differentiation. This in turn determines the probability of capturing the segments of the market for which the firm is competing.

We can express this relationship more formally with a stochastic function F(M) designating the probability of capturing a market segment:

$$F(M) = f(\partial, \beta, \Omega, e)$$

where $\partial = xi - ci < 0$ for every *i*th characteristic in the n-space, Ω is $yi - ci < 0$ for every i inthe n-space, where yi is an element of the product characteristic quantity vector y of the next most

competitive product to the product question. The partial derivatives of F(M) are negative with respect to ∂ but positive with respect to ß and Ω and e is the error term.

This formula suggests that the firm can capture the entire market by reducing ∂ to zero or by producing as many customized varieties of the products as there are potential customers through automation technology. The degree of the minimization of ∂, or the probability of capturing a market segment is determined by the degree of flexibility in product variation which is in turn dependent upon the use of automation technology. If Z is the number of models or varieties of a given product that are produced by the firm, the smaller the Z, the larger the size of the consumer population the firm is trying to appeal to, the larger the variability of tastes in this particular consumer population, and therefore the smaller the probability of capturing the consumers in that particular population.

This conceptual framework ascertains that increasing product differentiation increases the probability of capturing the market segments which in turn improves the economic performance of the firm. This new evaluation technique based on the degree of product differentiation is a more effective way of measuring economic performance than measuring performance through productivity by emphasizing the ability to lower the unit cost of a single product. The new conceptual framework ascertains that the probability of capturing the targeted total market increases with product differentiation and breaks the role of product differentiation out of the bounds of being strictly an attempt to increase sales. The ability to increase the number of product versions, on the other hand, is constrained by the degree of integration of automation technology to the production process. The less the firm uses automation technology, the fewer the number of product versions it can offer to consumers, therefore the less the probability of capturing the market segments and its economic performance will be lower.

By shifting the emphasis from economies of scale to economies of scope, the new conceptual framework suggests that the economic benefits of automation technology are:

- to increase product differentiation
- to shorten product lead times, and
- to improve product quality.

Within the wisdom of conventional economics, however, the main benefit of new technology is almost always recognized as the ability to lower units costs to improve productivity. The benefits that can be derived from automation technology are therefore overlooked as 'intangibles' and are not incorporated into an economic impact analysis.

4. THE ECONOMIC IMPACT ANALYSIS OF AUTOMATION TECHNOLOGY

We suggest that the economic benefits derived from automation technology considered to be 'intangibles' and are overlooked in conventional economics, can be quantified and incorporated into a standard method of economic evaluation.

The benefits of automation technology include increased flexibility, faster response to market shifts, improved product quality, and reduced lead times. These benefits represent a comparative advantage which may increase the competitiveness of the firm in the markets. Making the correct link between the benefits of automation technology and the traditional categories of accounting can remedy the problem of quantification.

One way of quantifying strategic benefits is to consider the variations in inventory which can be highly influenced by, for example, reduced lead times. Another way of quantifying benefits may be through sales expansion and revenue enhancement. Some of the benefits obtained from reduced lead time, for example, can be incorporated into an estimate of savings from inventory reductions. The process flexibility, better product flow, higher quality, and better scheduling, cut both Work In Process (WIP) and finished goods inventory levels. The reduction in average inventory levels provides a large cash inflow which can be captured in a Discounted Cash Factor (DCF) analysis. Better quality products can be quantified through reductions in the defect rate, waste, scrap, rework, inspection stations and inspectors, and reductions in warranty expense. Reductions in 'Accounts Receivable' can also be used to quantify the benefits from better quality products since the incidence of customers who defer payment until quality problems are resolved can be eliminated by producing better quality products. Since the new technologies also have the potential to increase sales, increased cash flow from the inventory reductions will continue in all future years by reducing the cost of sales. The major impact, however, will be on marketing advantage and on the ability to meet customer demand with shorter lead times and to respond quickly to changes in demand which can be estimated from past marketing and sales data. The generation of extra sales due to strategic benefits, such as reduced lead times, faster response to market shifts, and increased flexibility will result in an increased contribution to revenues.

The impact of reduced product costs on product prices and market share can be estimated from past sales and marketing performance of the product. Declining cash flows, market share, and profit margins may also be possible if the firm decides not to invest in automation technology since there is always the likelihood that some competitors may start using the new technology giving them the competitive advantage.

Savings in the cost of space, either through square-foot rental value or the annualized cost of new construction, is another benefit item which can be computed in terms of the opportunity cost of the space.

Identification of benefits within the standard accounting categories of sales, inventory, operating costs, and labor costs enables their quantification since data on these categories should be normally available in the accounting records of a firm.

The conceptual framework, which we will develop in more detail in the rest of this paper, highly differs from the conventional methods of economic impact analysis used in the current justification of new technologies. Current methods only consider possible reductions in costs already incurred using the existing technologies. Our proposed framework considers revenue enhancements due to strategic benefits such as reduced lead times and increased flexibility as well as cost reductions.

Using conventional methods, investment on new technology is typically evaluated against a status-quo alternative that assumes a continuation of current market share, selling price, and costs. A correct alternative to investment on new technology should also consider factors such as declining cash flows, market share, and profit margins. Once a new technology becomes commercially applicable, even if one company decides not to invest in it, the likelihood is that some competitors will. We integrate the possible impacts of changing market conditions and competitor behavior into the economic impact analysis via a computer program that simulates the probabilistic occurrences of alternative futures. This program readily interacts with the economic analysis program and provides a magnitude of benefits under different alternatives.

We suggest the framework depicted in Figure 1. Depending on the type of robot or automation system, certain cost or benefit categories identified in the framework can be omitted or expanded upon.

4.1. Identifying the benefits and costs associated with automation technology

This stage includes a detailed itemization of all the broad scale benefits and costs identified in the first stage within standard accounting categories and their quantification using the existing accounting records of a firm or manufacturing plant. Identification of costs and benefits within the standard accounting categories enables their precise quantification since data on those items should normally be available in the accounting records.

4.1.1. Strategic benefits

A. Reduction in inventory costs:

Reduction in inventory costs is a benefit item which is usually overlooked in most economic impact studies. The new automation technology, on the other hand, offers the possibility of reducing stock levels in work-in-process (WIP), finished goods and raw material inventory due to greater predictability of the production process, faster throughout times and due to the reduction of scrap and rework. Calculating the financial savings resulting from a given inventory reduction is more complex than normally assumed. The only benefit item that has been included in prior studies has been the direct

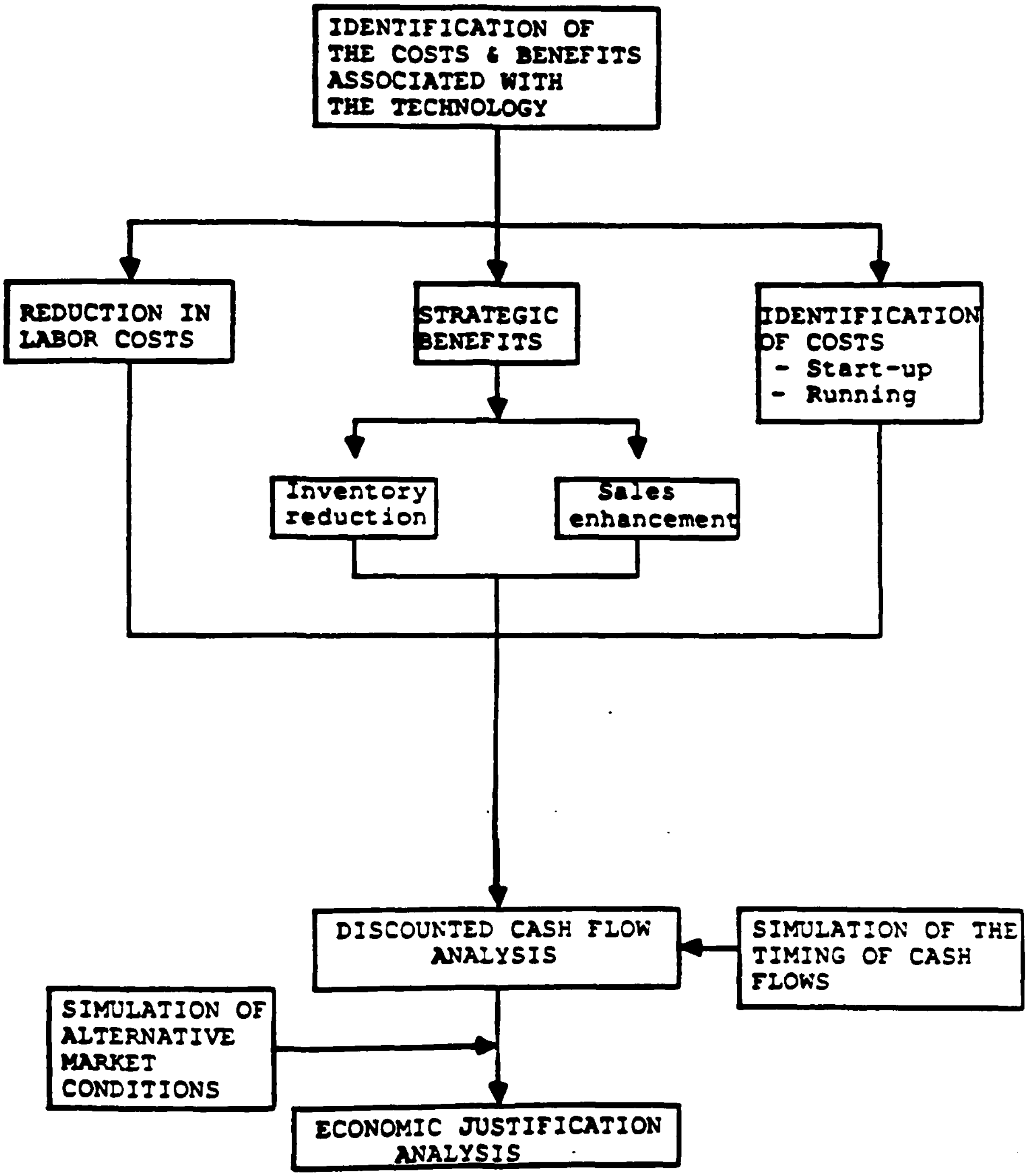

Figure 1 - The conceptual framework

cash savings (See for example Kaplan (1986) and Meredith (1985)). Within our conceptual framework, we suggest the inclusion of the benefits below:

a. Direct cash savings: Any savings in inventory costs due to the introduction of a new technology should be valued on the basis of old technology since the existing levels of stock are produced by existing manufacturing processes. Savings in the raw material stock should be considered not only in raw material inventory but also in WIP and finished goods inventory. Reduction in those inventory items should also be reflected to the direct labor content of WIP and finished goods, an item which is disregarded in prior studies. Since these reductions appear in the balance sheets as an increase in cash rather than an increase in profits, no additonal tax expense should be incurred.

b. Overhead savings: Since the reduction in inventory levels will alter the book value due to a reduction in fixed and variable overheads, a decrease in profits will be incurred. Since the decrease in profits is purely a reduction on paper, the tax liability will also fall which should be included as a benefit in the economic impact analysis.

The reduction in average inventory levels represents a large cash inflow at the time the automation technology becomes operational. Automation technology, on the other hand, reduces scrap and rework, increases the predictability of the production process, and shortens lead times. These improvements permit a major reduction in average inventory levels. The following is a list of benefits that should be included in the economic impact analysis:

BENEFITS	METHOD OF QUANTIFICATION
Shorter lead time	Reduction in WIP due to shorter lead times
Reduced delays	Reduction in assembly WIP due to the avoidance of unplanned shortages
Shorter lead time	Reduction in raw materials inventory
Shorter lead time and improved ordering policy	Reduction in finished goods inventory
Improved quality	Reduction in unwanted stock due to the avoidance of

	duplicate parts
Improved quality	Reduction in obsolete stock identified for disposal
Improved quality	Reduction in spares stock
Improved quality	Reduction in scrap material
Shorter delivery time	Reduction in finished product stock.
Lower tax liability	Overhead savings due to the reduction of inventory.

B. Sales enhancement:

A major advantage of automation technology is the generation of extra sales because of strategic benefits, such as reduced lead times, faster response to market shifts, and increased flexibility resulting in an increased contribution to revenues which can be identified through sales enhancement. The method of calculating the additional contribution primarily relates to the question, "What 'x' percent of increased sales can be expected from a 'y' percent reduction in say lead time?" Although it is difficult to determine the appropriate value of 'x' to insert in the above question, it is also true that an estimate should still be made of the potential increase in sales. This estimation can be made by using the existant information on sales lost due to rejection, late delivery, or not being able to meet customer needs in product specification. Another way to estimate sales enhancement is to forecast the growth in market share due to lower prices because of a reduction in product costs.

Automation technology reduces delivery times and increase the reliability of a firm which may improve the sales record and prevent potential sales from being lost. Sales lost due to delivery time, rejection of products, lower quality can be obtained from the marketing data. Marketing can also be used to provide an estimate of the percentage increase in sales due to reduced delivery time. The increase in sales can be easily converted to a reduction in overhead costs.

Automation technology also enables the earlier launch of new products to the market and therefore increase sales due to market penetration. While accurate dollar estimates of such a sales improvement is more difficult to obtain, estimates can be obtained by analyzing the marketing data. The following is a list of benefits due to sales enhancement that should be included in the economic impact analysis.

BENEFITS	METHOD OF QUANTIFICATION
Shorter lead time	Increased sales due to capacity increase and shorter set-up time
Shorter delivery time	Sales lost due to delays in ordering policy
Improved quality	Sales lost due to rejections
Improved quality	Sales lost due to incorrect parts
Increased flexibility in product	Sales lost due to the dissatisfaction of customer needs Potential increase in sales due to more precise products based on customer needs Potential increase in sales due to increased market penetration and more variable product mix
Increased market share	Potential increase in sales due to lower prices.

4.1.2. Reduction in labor costs

Automation technology reduces labor costs in the design, production and maintenance stages as well as in the supervision and inspection of the manufactured components or products. Although labor costs currently constitute 8 to 12% of total production costs, the magnitude in savings should still be included in the economic impact analysis.

Automation technology offers the potential to reduce labor costs in the design, production and maintenance stages as well as in supervision and inspection of the components. Since the technology offers the potential to produce components in precise accuracy, supervision and inspection costs should be signigicantly reduced. The benefits due to lower labor costs have been identified as reduction in:

- direct production labor costs due to fewer set-ups.
- support labor costs due to supervision and inspection.
- labor costs due to overtime payments.
- labor costs due to recruitment and training.
- inventory control labor costs due to lower WIP and finished goods inventory.
- labor costs due to tooling.
- labor costs in manufacturing design.
- labor costs due to maintenance.
- operating costs due to engineering and design
- labor costs due to the reduction of fitting and assembly requirements.
- labor costs in prototype production.
- labor costs in materials handling.
- labor costs in fixturing.
- production control costs.

4.1.3. Identifying costs associated with automation technology

It is important that the potential user of a new technology is aware of all the costs associated with the new technology, so that they can be adequately allowed for. Costs should be distinguished based on whether the costs incurred are 'one-off' type or 'ongoing' costs to be able to identify the timing and magnitude of cash flows. For example, the initial cost of customizing software should be separated from that of the software programmers required to keep the system operational.

The most immediate cost reduction in the introduction of new technology is the savings in labor costs. However, it is equally important to identify departments where extra staff may be needed to operate the system. Most automation technology, for example, involves the development of CAD software with the need for computer support staff to be considered.

Installation and start up costs should include:

- Computer Hardware
- Computer installation costs
- Software costs
- Cost of writing software in-house
- External costs for customizing purchased software

- Internal costs for customizing purchased software
- Consulting costs
- Company-wide education of personnel who need to understand the system
- Education and training cost of people who will directly operate the system
- Cost of temporary staff to install and run the system
- Cost of disrupted production during implementation
- Cost of subcontract work to avoid lost production during implementation
- Redundancy costs

The Running Costs should include:

- Hire or lease of hardware and software
- Maintenance contract for hardware and software
- Insurance
- Operating costs
- Consumables.
- Cost of Software updates.
- The management costs of the system.
- Programmer costs.
- Ongoing education and training.
- Staff upgrading costs.

4.2. Linking the economic impact analysis to Discounted Cash Flow (DCF) analysis

Once costs and benefits are quantified, the Discounted Cash Flow (DCF) analysis is aimed at measuring the economic returns on investment of new technology over time.

DCF analysis is based on the concept of "time value of money" approach. The basic idea underlying this approach is to translate the returns that can be obtained from a certain investment over a certain period of time into an amount equivalent to a value today. All cash inflows (benefits) and outflows (costs) associated with an investment are discounted to a certain value today so that the magnitude of investment is not larger than the present value of future savings. The discounting function serves to make cash flows received in the future equivalent to cash flows received at the present.

There are other capital investment evaluation methods such as the payback, payback reciprocal, and accounting rate of return which are simpler to use than the DCF method but ignore the time value of cash flows. These methods simply determine the period of time it takes for a project to return the original amount of money invested in it. This is particularly disturbing if we consider the long term commitment the implementation of automation technology requires. Since the potential benefits of

the technology can be realized only in the long term, any short run disruption can be used to abonden the new technology. By providing quantifiable objectives, the DCF method enables progress to be monitored in financial terms understandable to management.

A critical factor in DCF analysis is the timing of cash flows associated with the investment. Traditional capital investment evaluations generally assume that the total expenditure on a new technology takes place at a single point in time, with full cash flow savings similarly being achieved. With more complex technologies, however, the cost of commissioning and the loss of revenue during a period of run-up may seriously affect its financial viability. Cautious optimism is necessary in regard to the start-up period and the timing of expenditure. There may be an extensive period of proving robot fixtures, and control CAD software and hardware. The level of manning also may not reflect the time-scale of production build-up. Prior research on flexible manufacturing systems (Darnell and Dale, 1982; Kutay, 1988a) point out that a period of up to three to five years may be required between the first major expenditure on a system and the commencement of production. This delay may even be followed by additional years before full benefits are achieved.

Conventional techniques also assume that when a new technological innovation is commissioned, the corresponding outmoded facility is terminated. Therefore, incremental cash flows of both cash and savings, occupy the same time scale. This assumption is certainly invalid in the case of automation technology whose complexity may complicate its realization and increase the time at which it can be considered to be fully commissioned.

This problem will be resolved by developing a computer program to regulate the timing of cash flows with due provision being made for lower savings during the start-up period. Figure 2 depicts simplistic assumptions incorporated within a traditional evaluation, whereas Figure 3 reoresents the more complex way in which cash flows change with time in a more complex automation technology. The computer program will determine the net cash flow by evaluating the individual cash flows separately based on three DCF methods:

1) Internal Rate of Return (IRR): The IRR is the interest rate that discounts an investment's future cash flows to the present so that the present value of the cash flows exactly equals the cost of investment. The IRR is, in fact, the interest rate that is earned on the investment. Once the IRR is found, it will be compared with the minimum rate of return which is the firm's cost of capital.

2) Net Present Value (NPV): NPV of evaluating an investment involves discounting all the project's cash flows to their present value using a target rate of interest, which is the firm's cost of capital. The computation of the NPV will rest on the assumption that all inflows from the investment are reinvested at the firm's target rate of return.

3) Profitability Index (PI): PI will be computed to convert the NPV to comparable figures with other investments the firm may be considering to undertake. PI is the ratio of the present value of cash inflows to the present value of the cash outflows.

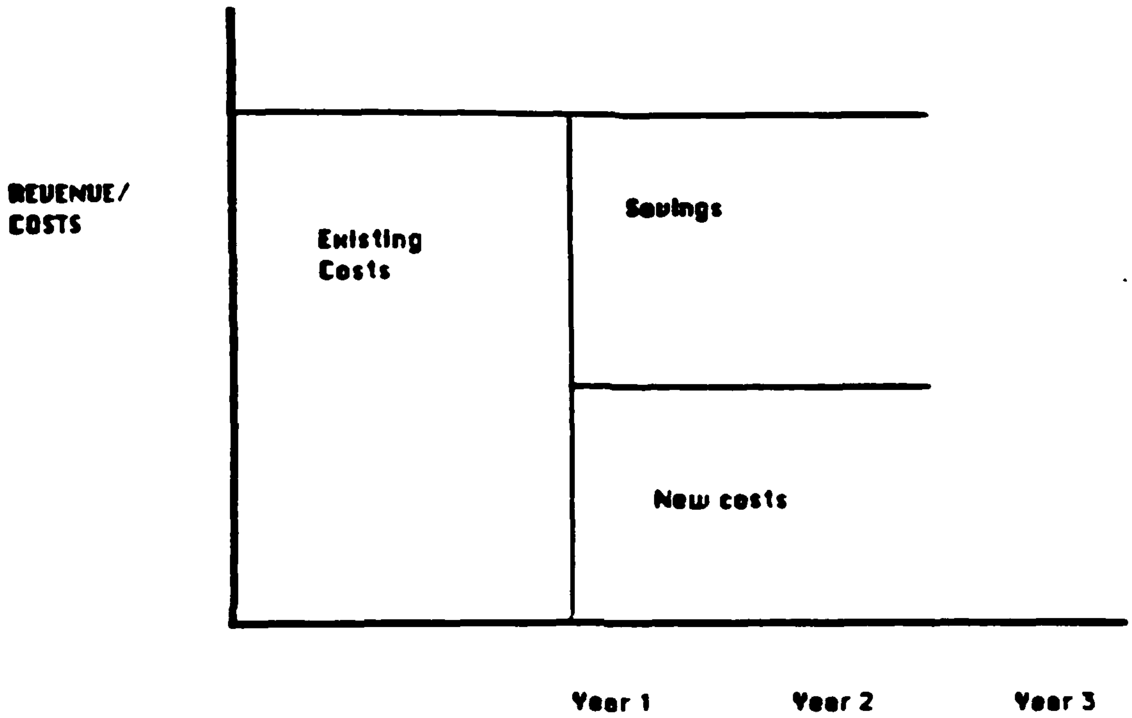

Figure 2 - Conventional assumption of cash flow

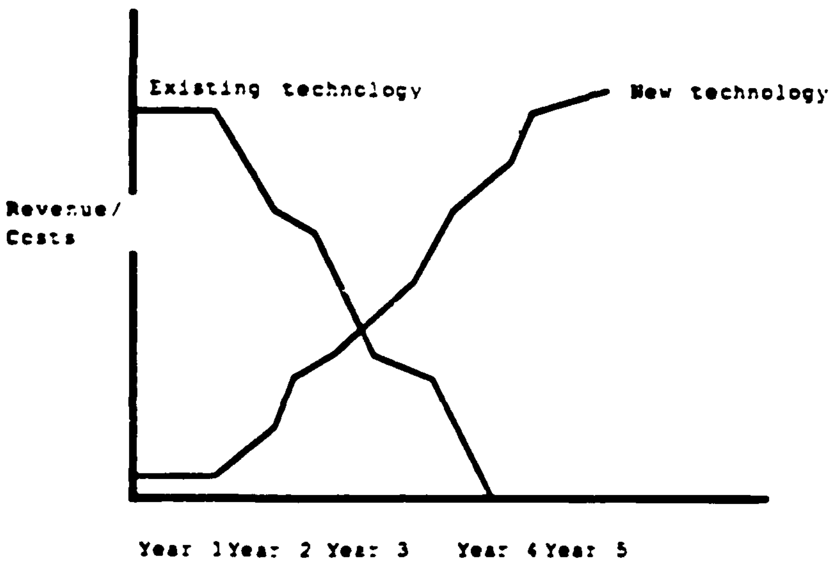

Figure 3 - Cash flow with automation technology

The DCF analysis also requires the computation of the cost of capital so that the return on investment on a new technology can be comparable to a target value. Theoretically, the cost of capital can be computed as the weighted average of the rates paid to various investors. For many firms, however, the cost of capital may be difficult to compute because the cost of borrowing or the cost of equity funds may change with changes in the economy, government actions and changes in the risk of various types of investments. The DCF approach, on the other hand, usually goes wrong when firms set arbitrarily high target rates or "hurdle rates" for evaluating the returns on investment.

The computer program will compute the cost of capital based on three methods:

1. The opportunity cost of capital, which is the return available in the capital markets for investments of the same risk.

2. Cost of Common Stock, which is the ratio of dividend per share to market per share.

3. Cost of Preferred Stock, which is the ratio of preferred dividend per share to market price of preferred share.

4. Cost of Long-Term Debt.

5. Weighted Average Cost of Capital which is the weighted averages of Long-Term Debt, Cost of Preferred Stock and Cost of Common Stock based on the proportion of the capitalization of the debt of a firm.

4.3. Integration of the variability of market conditions to economic impact analysis

Using conventional methods, investment on new technology is typically evaluated against a status-quo alternative that usually assumes a continuation of current market share, selling price, and costs. Correct alternative to investment on new technology should also consider a situation of declining cash flows, market share, and profit margins. Once a new technology becomes commercially applicable, even if one company decides not to invest in it, the likelihood is that some competitors will.

In this study, the possible changes in market share, selling price, and costs will be simulated by a computer program based on decision systems analysis. The computer program will be based on the probabilitic occurrences of possible alternatives which results if a firm decides to authorize or kill the investment on a new technology. This program will readily interact with the economic evaluation program as depicted in Figure 4.

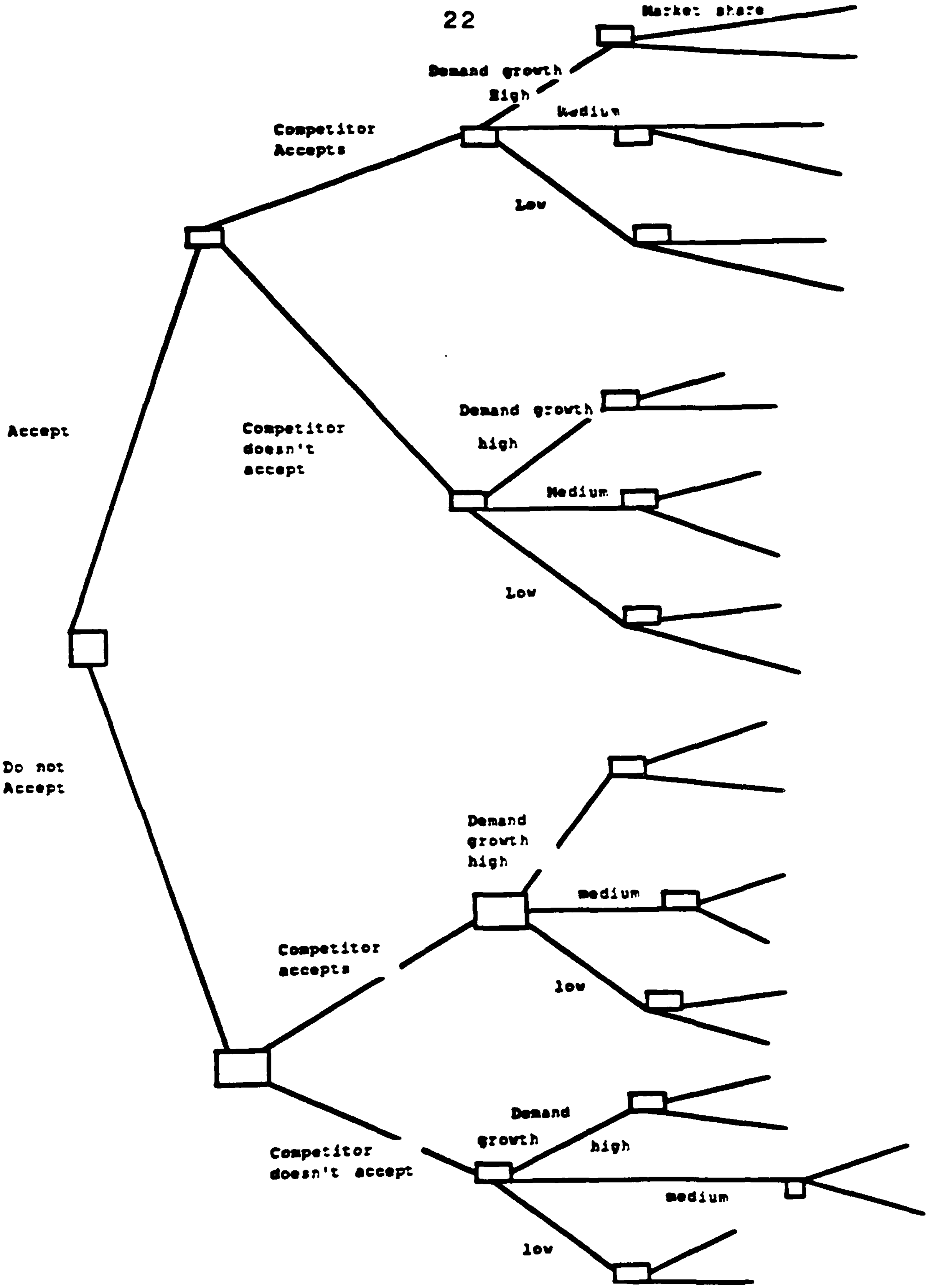

Figure 4 - Simulation of market conditions

5. CONCLUDING COMMENTS

One of key arguments of this paper is that the lack of an economic analysis technique specifically aimed at assessing the benefits of automation technology is the major cause of the slow rate of investment on new technologies in the United States. The paper addressed this problem by developing a new conceptual framework based upon the premise of increased probability of capturing the market segments through economies of scope. The paper also demonstrated that the proposed framework is conceptually implementable in practice and can be integrated into a standard method of economic evaluation understandable to company executives, accountants and economists. The arguments supporting the line of reasoning set forth in this paper need to be empirically verified by further research. This effort, nevertheless, is meant to provide a new methodology upon which future economic impact studies of new automation technology may be based.

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